

SECTION J.2

PROJECT BACKGROUND

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J.2 Introduction

The purpose of this section is to provide background information relative to the FEMP, in general, and more specifically, relative to OU4. The following discussion provides background information on activities performed with respect to OU4 and history and characteristics of the Silo 3 material.

J.2.1 The FEMP

The FMPC (which the FEMP was formerly known as) produced high purity uranium metal products for the DOE and its predecessor agencies from 1952 to 1989 on this 1,050-acre site. Thorium was also processed, but on a smaller scale, and stored on site. Production activities ceased in 1989, and the production mission was formally ended in 1991. The Fernald site was included on the CERCLA NPL in 1989. The current mission of the site is the safe environmental restoration of the site in accordance with all ARARs and TBCs.

There are five defined areas, known as operable units, undergoing remediation at the FEMP. These operable units were defined based on their locations or the potential for similar technologies to be used in the ultimate cleanup. The operable units for the FEMP are defined as follows:

- ! OU1 - Waste Pits 1 through 6, the Burn Pit, the Clearwell, and berms, liners, and soil within the operable unit boundary;
- ! OU2 - Two flyash piles, other South Field disposal areas, two lime sludge ponds, solid waste landfill, berms, liners, and soil within the operable unit boundary;
- ! OU3 - Former Production Area and production associated facilities and equipment (includes all above- and below-grade improvements) including, but not limited to, all structures, equipment, utilities, drums, tanks, solid waste, waste product, thorium, effluent lines, the K-65 transfer line, wastewater treatment facilities, fire training facilities, scrap metal facilities, feedstocks, and coal pile;
- ! OU4 - Concrete Storage Silos 1 through 4, berms, decant tank system, and soil within the operable unit boundary; and
- ! OU5 - Environmental media, including groundwater, surface water, and soil not included in Operable Units 1 through 4.

[FIGURE J.2-1]

Figure J.2-1 identifies the operable units at the FEMP as the shaded areas, and identifies the fenceline at the FEMP boundary with the dashed line.

Remediation of the FEMP is being conducted under CERCLA, as amended, and the NCP, 40 CFR Part 300.

J.2.2 Operational History of OU4

This section discusses the process history and origins of all the silo materials with specific detail on Silo 3 material.

The storage silos were constructed for the transfer and storage of two basic forms of materials known as "hot" raffinates and "cold" metal oxides. The following discussion has been included from the final OU4 Remedial Investigation Report to explain the origins of the cold metal oxides and describe the processes at the former FMPC refinery to generate the stored material. Also discussed are the pertinent aspects of material handling to show how the material were generated and transferred to Silo 3.

The FMPC refinery processed two basic classes of materials: (1) pitchblende ores as they were mined and shipped to the FMPC and (2) other uranium concentrates that had already been refined to some degree. This second class of materials included uranium concentrates that had undergone a preliminary refining process at an off-site mill and wastes recovered at various stages of FMPC operations.

Uranium-bearing ores, as they are mined, contain not only uranium, but also equilibrium (activity) concentrations of uranium progeny (i.e., the isotopes of other elements formed through the sequential radioactive decay chains that begin with U-235 and U-238). These progeny, which include radium, are removed in either a preliminary milling process or in the refining process (if the ores are not preprocessed through a mill). Thus, when the FMPC refinery processed pitchblende ores, the refinery wastes contained a high concentration of the radioactive uranium progeny. These refinery wastes were known as "hot" raffinates.

The term "hot" was used to indicate that the wastes contained a high concentration of the radionuclide radium (Ra)-226 and gamma-emitting progeny that result in a significant direct penetrating radiation exposure rate. When the FMPC processed uranium concentrates that had been preprocessed through a uranium mill, a significant portion of the Ra-226 and the gamma-emitting progeny had already been removed and were thus termed "cold" metal oxides. However, some of the thorium progeny of uranium (i.e., thorium [Th]-230) remained within the uranium concentrates due to the inefficiency of the mill in removing this metal, so even though the wastes are "cold," they are radioactive.

J.2.2.1 History of Silo 3

Silo 3 was constructed in 1952 for the storage of byproduct metal oxides generated through the operation of the FMPC refinery. Unlike Silos 1 and 2, which received byproducts from the processing of ores from only three mines, Silo 3 received metal oxides generated consequential to all FMPC refinery operations from May 1954 until late 1957. During this time period, the FMPC refinery processed pitchblende ores and uranium ore concentrates received from a number of foreign and domestic uranium mills.

Fernald-generated material in Silo 3 is a byproduct of refinery operations conducted in Plant 2/3 and supporting structures at the facility. Pitchblende ores were received at Plant 1 of the FMPC site where the ores were thawed (if necessary), milled, and assayed for their uranium content. Milling took place in a Williams mill, where the ores were ground until they would pass a 100-mesh sieve. Milling was performed to facilitate the digestion process. The milled ores, following assay, were conveyed to the Plant 1 ores silos for storage until they were processed in the refinery (Plant 2/3). At the refinery, the milled ores were transferred to digester tanks by batch. Each batch varied from 1,820 kg (4,000 lb) to 2,270 kg (5,000 lb) of uranium and 2,270 kg (5,000 lb) to 4,550 kg (10,000 lb) of net feed. Nitric acid and water were added to the ores in the digesters to yield a final slurry concentration of 200 grams of uranium per liter and 3 Normal excess nitric acid. Following a typical three-hour digestion, the digest slurry was transferred to a feed holding tank in the extraction area of the refinery.

The uranium extraction system at the FMPC site, at the time of K-65 processing, employed a series of three perforated plate pulse columns, including an extraction column, a scrub column, and a re-extraction column. The aqueous feed slurry from the hold tank was introduced into the top of the extraction column. An organic extraction, 33.5 percent by volume tributyl phosphate (TBP) in an inert purified kerosene diluent, was introduced into the bottom of the same extraction column. The combined liquid phases were pulsed through the stationary perforated plates, with the aqueous feed solution passing down and the organic phase moving up through the column. The organic extractant flow rate and the feed stream flow rate were controlled to maintain a constant uranium saturation level in the organic product stream. The uranyl nitrate solution was removed from the aqueous slurry of the organic extractant. Extraction of the uranium from the ores was essentially completed when the organic product stream left the top of the extraction column.

The remaining metals and other impurities in the pitchblende ores left the bottom of the extraction column. This byproduct stream was known as K-65 raffinates. The K-65 raffinates were freed of the organic phase in a disengagement chamber at the base of the extraction column. Despite this disengagement process, considerable quantities of entrained TBP remained in the raffinate leaving the column. To recover these reusable concentrations of TBP, the raffinates were transferred to a single stage mixer settler where the raffinates were contacted with continuously recycled kerosene to recover the remaining TBP.

While the TBP extraction system was relatively specific toward uranyl nitrate, other nitrate compounds, such as thorium nitrate, present in the feed slurry were physically entrained in the organic product phase leaving the extraction column. To remove these impurities from the feed stream, a second purification step was performed in the scrub column to achieve product quality standards. In the scrub column, the organic product stream from the extraction column

entered the bottom while deionized water entered the top of the column. During the continuous flow through the scrub column, essentially all of the remaining metallic impurities were transferred to the aqueous phase, together with a small quantity of uranium. The aqueous phase was directed back to the extraction column to recover the remaining uranyl nitrate. The pure organic phase continued through the final re-extraction column where the TBP-kerosene was separated from the uranyl nitrate. The operation of the re-extraction column is not relevant to the generation of the K-65 material and is, therefore, not presented. The impurities residing in the aqueous phase from the scrub column were transferred to the K-65 raffinates leaving the extraction column.

The kerosene-washed K-65 raffinates were filtered through a precoated rotary vacuum filter to remove suspended solids. Most of the gamma-emitting uranium progeny, and radium, were filtered out in this step.

In the case of pitchblende ore processing, the filter cake was transferred to Silo 2 to hold the radium and other precious metals present in this byproduct fraction for the planned eventual return to the Belgian Congo. The filtrate from the vacuum filter was subjected to further waste processing and eventually was transferred to Silo 3. In the FMPC processing of uranium concentrates, the major fraction of metal impurities, including radium, had been previously removed from the concentrates by the uranium mills prior to transfer to the FMPC site. Significant activity concentrations of other radionuclides in the uranium decay series, including thorium, remained in the concentrates due to the variations in the efficiency of the removal at the mill.

The entire kerosene-washed raffinate stream from the extraction column during ore concentrate processing, and the filtrate from the rotary vacuum filter during operation involving pitchblende ores, were processed in a similar fashion to produce the cold metal oxides present in Silo 3 (Figure J.2-2). These materials were transferred to a series of agitated holding tanks in the refinery area. These surge tanks fed a set of evaporators where approximately 90 percent of the liquids were evaporated and the remaining ten percent concentrates were withdrawn for further processing. Evaporator temperatures ranged from 90°C (200°F) to 120°C (250°F). The concentrates from the evaporator were transferred to one of two processing operations depending on when they were transferred. From plant start-up through the mid-1950's, the concentrates were transferred to a spray calciner. The spray calciner operated at a temperature of 510°C (950°F) to remove the remaining liquids and convert the metal nitrates present in the concentrates into oxides.

Due to operational difficulties experienced with the spray calciners, a second process was installed to complete the drying of the concentrates. In this process, the concentrates from the evaporators were transferred to a drum dryer where the materials were spread in a rotating dryer. In the dryer, liquids were removed from the concentrates by centrifugal force. The drum-dried concentrates were then transferred to a rotary calciner to remove the remaining liquids and to complete conversion of the metal nitrates into oxides. The concentrates were retained in the furnace zone at 650°C (1,200°F) to 820°C (1,500°F) for approximately 10 minutes.

The finely powdered, dried metal oxides were transferred to a surge hopper. From this hopper, the dried metal oxides were pneumatically conveyed to Silo 3 through a pipeline in the concrete trench to Silo 3. At the Drum Handling Building, the Silo 3 transfer line ran above grade on a pipe rack to the top of Silo 3. A dust collector, which was used to control discharges to the atmosphere resulting from the discharge of the powdered material into Silo 3, was located at the top of the silo. Silo 3 was filled to its present level using this rotary calcining process. No material, except samples, have been removed from Silo 3 since filling in 1957.

Following a programmatic decision in early 1957 to use raffinate surface impoundments, the spray calcining and rotary calcining systems were eventually abandoned. As a result, Silo 4 was never employed for the storage of cold metal oxides and remains empty. Inspections completed on Silo 4 during the OU4 RI-related site investigations confirmed that no waste materials were present within the silo.

J.2.3 Site Characteristics

J.2.3.1 Meteorology

Information on the local climate was gathered from two primary sources: an on-property meteorological system installed at the FEMP in 1986 and the National Weather Service Office at the Cincinnati/Northern Kentucky International Airport.

Winds

The FEMP meteorological system was used by the National Oceanic and Atmospheric Administration (NOAA) to examine the complexity of the local wind field at the FEMP site. The study showed that two major features, the Great Miami River Valley and the ridges surrounding the site, affect the wind patterns. Wind flow data from the Cincinnati airport was found to be representative of local conditions to serve as a database for the years prior to the installation of the on-property meteorological system.

Figure J.2.3 shows the yearly wind patterns at the site recorded from a 10-m tower for the year 1992. Prevailing winds are generally from the southwest and west-southwest. The annual frequency distribution is noted on the scale of the figure as is the stability class distribution, a parameter that is used in air dispersion modeling. Atmospheric stability is a measure of the potential for vertical mixing, both mechanical and thermal. It is classified

Figure J.2-2

from A through F based on the wind speed, net solar radiation, and cloudiness. A classification of F is the most stable and A the most unstable.

Precipitation

The average annual precipitation for the Cincinnati area for the period of 1960 through 1989 was 40.56 inches and ranged from 27.99 inches in 1963 to 52.76 inches in 1979. The highest precipitation occurs during the spring and early summer. The maximum 24-hour rainfall event of record occurred in March 1964 when 5.21 inches fell. Precipitation is typically lowest in late summer and fall.

The average annual snowfall for the 1960 to 1989 period was 23.5 inches, with the heaviest snowfall usually occurring in January. The maximum monthly snowfall of 31.5 inches occurred in January 1978. The maximum 24-hour snowfall event of record occurred in March 1968 when 9.8 inches was recorded at the Cincinnati/Northern Kentucky International Airport.

Temperature

The regional climate is defined as continental, with temperatures ranging from a monthly average of 29.2°F in January to 75.7°F in July. The highest temperature recorded from 1960 through 1989 was 103°F in July 1988, and the lowest was -25°F in January 1977. The average number of days per year with a minimum temperature of 32°F or less is 109 days; the average number of days per year with a maximum temperature of 90°F or greater is 20 days. Frost depth ranges from 30 to 36 inches.

J.2.3.2 Topography

Maximum elevation along the northern boundary of the FEMP property is a little more than 700 ft above mean sea level (MSL). The former Production Area and Waste Storage Area rest on a relatively level plain at about 580 ft above MSL. The plain slopes from 600 feet above MSL along the eastern boundary of the FEMP to 570 ft above MSL at the K-65 silos, and then drops off toward Paddys Run at an elevation of 550 ft above MSL.

J.2.3.3 Surface Water Hydrology

Surface waters on and adjacent to the FEMP site are the Storm Sewer Outfall Ditch, Paddys Run, and the Great Miami River. The Storm Sewer Outfall Ditch originates within the FEMP site and flows toward the southwest where it enters Paddys Run, which flows southward along the western boundary of the facility. Paddys Run is a tributary of the Great Miami River. The Great Miami River flows within 0.75 mile of the facility's eastern boundary and discharges into the Ohio River approximately 24 river miles from the FEMP effluent line. The FEMP site is located within the Great Miami River Basin drainage but above the river's present day floodplain.

Figure J.2.3

J.2.3.4 Groundwater Hydrology

The Great Miami Aquifer is the principal aquifer within the FEMP Study Area and has been designated a sole source aquifer under the provisions of the Safe Drinking Water Act. The buried valley in which it occurs varies in width from about 0.5 mile to more than 2 miles, having a U-shaped cross section with a broad, relatively flat bottom, and steep valley walls. This valley is filled with extensive deposits of sand and gravel that range in thickness from 120 to 200 ft in the valley to only several ft along the valley walls, along with scattered silt and clay deposits.

Contained within the sand and gravel that underlies much of the FEMP property is a relatively continuous, low-permeability clay interbed ranging from about 5 to 15 ft in thickness. The clay interbed occurs at an approximate elevation of 460 ft, and divides the aquifer into upper and lower sand and gravel units, referred to as the Upper Great Miami Aquifer and the Lower Great Miami Aquifer.

The hydraulic conductivity of the Great Miami Aquifer has been investigated in reports and regional studies. Values range from 120 to 775 ft per day (ft/day) with most of the values in the 270 to 335 ft/day (0.95 to 0.12 cm/s) range. More recent groundwater flow modeling studies have shown values ranging between 350 and 600 ft/day (0.12 to 0.21 cm/s) for hydraulic conductivity. No significant variation has been shown to occur between the upper and lower halves of the aquifer, although studies in similar hydrogeologic regimes have shown a gradual coarsening of sediment does occur deeper in the buried valley sequences.

J.2.4 Waste Characteristics

This section provides summary descriptions of the physical, chemical, and radiological characteristics of the Silo 3 material. These descriptions are based on information in the following documents: 1) the Remedial Investigation Report for OU4, 2) the Feasibility Study Report for OU4, 3) the Evaluation of Silo 3 Alternatives, 4) the Nuclear Fuel Services Final Report on the Treatability Study for the Stabilization of the Silo 3 Wastes, and 5) Review of Ore Concentrates from which Silo 3 material is derived.

J.2.4.1 Physical Characteristics

Material in Silo 3 are dried metal oxides that were air-conveyed into the silo. The conveyed material was cold raffinate from the extraction columns. The material was washed and dried, then fed into a spray calciner or a gas fired rotary kiln where the nitrates were completely decomposed, yielding a solid oxide product of the metal impurities originally present in the ore concentrate. The dried metal oxide product was removed by a set of cyclones discharging into a storage hopper and periodically the collected solids were transferred by air pressure into the silo. Thus, the material in Silo 3 is a dry powder-like material. During the 1989 Silo 3 sampling operation, field investigation personnel visually observed the material in the silo to be relatively evenly distributed within the tank with only minor peaks beneath the inlet ports.

The material in Silo 3 is brown with a tone that varies from dark to reddish brown. As a result

of the evaporation and calcination of this material, the water content is very low, ranging between 3.7 and 10.2 percent.

Approximately 90 percent of the Silo 3 material, based on a weight fraction of the material, passed through a 200-mesh sieve (0.074 mm) during testing for the OU4 RI. This indicated that the majority of the material was silt size or less.

Analysis of the Silo 3 material by Argonne National Lab, June 1996, used two other techniques to evaluate particle size distribution. The very fine particle material (0.001 to 1 μm) was analyzed using a Laser Light Scattering technique on a dispersed, suspended fraction of the Silo 3 material. Based on the intensity of reflected light, it was determined that the small particulate in this size range averaged 0.2 μm , with a peak range of 0.05 to 0.35 μm . Argonne also used Scanning Electron Microscopy and computer software to determine the size distribution based on the number of particles greater than 0.5 μm . This analysis indicated that approximately 90 percent of the particles counted ranged in size between 0.5 and 5 μm . The Argonne report is included as Attachment J.4.30.

All the samples collected from Silo 3 were nonplastic. The density of the material in Silo 3 ranges from approximately 29 lbs/ft³ to 58 lbs/ft³. This range in density would result in a corresponding range of approximately 1,950 tons to 3,925 tons of Silo 3 material requiring treatment under this contract.

The dispersibility of the Silo 3 material causes it to be a potentially serious respiratory hazard to the remedial worker due to the levels of Th-230 (Table J.2-4). This dispersibility becomes quite important in understanding treatment needs for the Silo 3 material, the importance due to the Th-230 content of the material, and the percentage of the Silo 3 material which exist as very small particles. The net result is a potential respiratory hazard which must be contained during the removal, treatment, and disposal of the material. This respiratory hazard is the primary hazard associated with the Silo 3 material, since there is very little gamma exposure resulting from the material.

J.2.4.2 Chemical Constituents

Inorganic Constituents

A summary of the inorganic constituents detected in samples from Silo 3 is provided in Table J.2-1. Of the 23 inorganic constituents detected, the predominant metals included aluminum, calcium, iron, magnesium, potassium, and sodium. Other metallic constituents include arsenic, cobalt, copper, lead, manganese, nickel, and vanadium. Concentration ranges for the predominant constituents are 10,800 - 23,700 mg/kg for aluminum; 21,300

- 39,900 mg/kg for calcium; 13,900 - 67,600 mg/kg for iron; 38,200 - 80,900 mg/kg for magnesium; 1,300 - 22,800 mg/kg for potassium; and 22,900 - 51,700 mg/kg for sodium.

In addition, high sulfate levels, 15 weight percent by dry weight, were observed in a single sample of Silo 3 material during crucible melts performed as treatability studies by Batelle

National Laboratories as part of the OU4 FS.

Organic Constituents

In 1989, four samples were collected from Silo 3 for Hazardous Substance List (HSL) organic analysis. HSL volatile organic data from the 1989 sampling were rejected due to missed sample holding times. Results for polynuclear aromatic hydrocarbons are not seriously effected by the extended holding times and can remain basically unchanged for years. Also, aroclors (polychlorinated biphenyls) and pesticides are very persistent and show little tendency toward degradation, either chemically or biologically. Therefore, data for these analytes were retained during validation. With the exception of 2-nitrophenol and 4-nitrophenol, which were each detected in a single sample at a value less than the sample quantitation limit, no organic compounds were found.

Although the majority of the organic analyses were rejected due to missed holding times, there is little likelihood that organic constituents would be present in the Silo 3 material due to the calcining process performed on the material. The temperature, at which the calcining process was performed, would have destroyed or driven off any volatile organic constituents that may have been present in the material.

Toxicity Characteristic Leaching Procedure and EP-Toxicity Analyses

Eleven samples were submitted for metals Extraction Procedure (EP)-Toxicity analyses. Results of these analyses are presented in Table J.2-2. The concentration of the following metals in leachate exceeded its respective toxicity characteristic limit established in 40 CFR Part 261.24: arsenic, cadmium, chromium, and selenium. In addition, one sample from Silo 3 was submitted for the Toxicity Characteristic Leaching Procedure for radiological constituents. Results for this sample are provided in Table J.2-3 .

J.2.4.3 Radiological Constituents

The results of the 1989 samples collected from Silo 3 are presented in Table J.2-4 . Twelve radionuclides, were identified including actinium-227, lead-210, protactinium-231, radium-224, radium-226, radium-228, thorium-228, thorium-230, thorium-232, uranium-234, uranium-235, and uranium-238. Thorium-230 had the highest activity concentration, ranging from 21,010 - 71,650 pCi/g.

Table J.2-1 Summary of Chemical Analyses for Silo 3 Material¹

Analyte	Arithmetic Mean (mg/kg)	Upper 95% CI on A Mean (mg/kg)	Range of Detection (mg/kg)
Aluminum	17,200	19,800	10,800 - 23,700
Arsenic	1,950	3,170	532 - 6,380
Barium	217	278	118 - 332
Beryllium	24.2	29.1	10-39.9
Cadmium	60	94	21.5 - 204
Calcium	29,400	33,400	21,300 - 39,900
Chromium	288	395	139 560
Cobalt	2,100	2,890	1,100-3,520
Copper	2,550	3,340	1,610-7,060
Iron	37,800	52,200	13,900 - 67,600
Lead	1,730	2,380	646 -4,430
Magnesium	58,600	68,900	38,200-80,900
Manganese	4,380	5,160	2,420-6,500
Mercury	0.4	0.7	0.3-0.69
Nickel	3,150	4,290	1,760-6,170
Potassium	7,260	14,000	1,300-22,800
Selenium	174	229	101 - 349
Silver	16	18	9.2-23.8
Sodium	36,100	40,800	22,900 - 51,700
Thallium	21	56	4-73.9
Vanadium	1,820	3,490	418-4,550
Zinc	450	535	301-672

¹ Data taken from Table 4-20 of the Remedial Investigation Report for Operable Unit 4.

Table J.2-2 EP Toxicity Results for Silo 3 Material - 1989¹

Analyte	Frequency of Detection	Mean (mg/L)	Standard Deviation (mg/L)	Minimum (mg/L)	Maximum (mg/L)	RCRA TC Limit (mg/L)
Arsenic	9/11	9.481	12.393	ND ²	41.5	5.0
Barium	11/11	0.080	0.046	0.02	0.156	110.0
Cadmium	11/11	0.847	1.740	0.108	6.32	1.0
Chromium	11/11	5.05	3.22	0.336	11.9	5.0
Lead	7/11	0.239	0.327	ND	1.01	5.0
Mercury	2/11	0.0005	0.0009	ND	0.003	0.2
Selenium	11/11	2.65	3.00	0.92	11.7	1.0
Silver	1/11	0.007	0.008	ND	0.032	5.0

¹ Data taken from Table 4-21 of the Remedial Investigation Report for OU4.

² ND - Not Detected

The sample results for Silo 3 material are consistent with process knowledge. Radionuclides detected were at expected levels. Lower grade ores were refined at the FEMP site during the period of Silo 3 operation in comparison to the high assay pitchblende, which produced the raffinates in Silos 1 and 2. Therefore, the concentration of Th-230 is lower than the Ra-226 concentrations in Silos 1 and 2.

Airborne radon measurements are routinely collected both on and off the FEMP property as part of the ongoing FEMP Environmental Monitoring Program. Because Ra-226 was removed from the material placed in Silo 3, the radon levels associated with Silo 3 wastes (flux rate approximately 71 pCi/m²·s) are relatively low in comparison to the levels in Silos 1 and 2 (flux rate approximately 7,000 pCi/m²·s), however, the headspace concentration of radon in Silo 3 is approximately 300,000 pCi/L.

Routine airborne radon monitoring at the FEMP is conducted as part of the Environmental Monitoring Program. Results for radon monitoring performed from 1989 through 1992 are summarized below. More details are available in the annual FEMP Environmental Monitoring reports.

Airborne radon measurements are routinely collected both on and off the FEMP property, as part of the ongoing environmental monitoring program. The FEMP monitors radon concentrations at 21 locations along the FEMP perimeter fence. The average annual radon concentration along the FEMP fenceline for 1989 through 1992 was 0.74 pCi/L in 1989,

Table J.2-3 TCLP Radiological Analyses for Silo 3 Material¹

Radiological Parameters	Concentration (pCi/L)
Actinium-227	5.54 ± 1.94
Gross alpha	3,150 ± 830
Gross beta	670 ± 340
Lead-210	87.1 ± 9.2
Polonium-210	245 ± 110
Protactinium-231	< 647
Radium-226	2,455 ± 558
Radium-228	< 110
Thorium-228	3.17 ± 1.42
Thorium-230	10.4 ± 2.8
Thorium-232	< 1
Uranium-234	92.2 ± 13.8
Uranium-235/236	5.09 ± 1.59
Uranium-238	86 ± 13

¹ Data taken from Table 4-22 of the Remedial Investigation Report for OU4.

0.74 pCi/L in 1990, 0.90 pCi/L in 1991 and 0.57 pCi/L in 1992. The maximum annual radon concentration recorded during this period was 1.5 pCi/L observed at the radon monitoring station located at the northeast corner of the site.

J.2.5 Nature of Contamination

Background Data

The 95th percentile of the background data distribution for selected analytes in environmental media (e.g., surface soil, perched groundwater, and Great Miami Aquifer) was used to distinguish waste-related contamination in those media from naturally occurring or other nonsite-related levels of chemicals and radionuclides (Table J.2-5). The following is a brief discussion of the use of background data in identifying waste-related constituents. A more detailed discussion is presented in Appendix D, Section D.2 of the Remedial Investigation Report for OU4.

Table J.2-4 Summary of Radionuclide Analyses for Silo 3 Material¹

Analyte	Arithmetic Mean (pCi/g)	Upper 95% on A Mean (pCi/g)	Range of Detection (pCi/g)
Actinium-227	618	925	234 - 1,363
Lead-210	2,620	3,480	454 - 6,427
Protactinium-231	487	627	266 - 931
Radium-224	290	367	64 - 453
Radium-226	2,970	3,870	467 - 6,435
Radium-228	297	406	82 - 559
Thorium-228	590	747	459 - 996
Thorium-230	51,200	60,200	21,010 - 71,650
Thorium-232	656	842	411 - 1451
Uranium-234	1,480	1,730	348 - 1,935
Uranium-235/236	93.6	117	42 - 158
Uranium-238	1,500	1,780	320 - 2,043

[†] Data taken from Table 4-19 of the Remedial Investigation Report for OU4.

The site-specific background data set for soil consists of a series of soil samples collected approximately three to five miles from the FEMP site. The Risk Assessment Work Plan Addendum clarifies the statistical treatment of these data to determine the background concentrations used for the OU4 RI. Background concentrations in surface and subsurface soil were determined based on (1) direct analysis of regional soils at two depths (i.e., 0 to 6 inches and 48 to 54 inches), (2) the assumption of secular equilibrium in the radioactive decay process, and (3) the recognition that certain organic compounds and radionuclides do not occur naturally.

The 95th percentile of the background data distribution for the 0- to 6-inch interval and the 48- to 54-inch interval were compared with OU4 analytical results to distinguish waste-related contamination from naturally occurring or other nonsite-related levels of chemicals and radionuclides in surface and subsurface soils of OU4. Organic compounds in the soil and groundwater were considered to be waste-related regardless of their concentration. Radiological and chemical constituents, both inorganic and organic, in the silo wastes were considered to be waste-related contamination by definition.

Background concentrations were estimated for groundwater proximal to OU4. Principal hydrologic units underlying OU4 include an upper, variably saturated glacial overburden unit and the lower Great Miami Aquifer. The Great Miami Aquifer is unconfined, within a largely homogenous sand and gravel unit separated from the base of the glacial overburden by a

vadose zone, which is an average of 20 feet thick.

Background concentrations are given in Table J.2-5 for the glacial overburden unit and the Great Miami Aquifer and are based on the sample results provided in the FEMP RI/FS document "Characterization of Background Water Quality for Streams and Groundwater." These values represent the 95th percentile of the data distribution except as noted. Background concentrations in the Great Miami Aquifer are from up gradient wells located off-site from OU4. The natural water chemistry of the Great Miami Aquifer varies moderately between two hydrologic domains near OU4: the Shandon domain and the Dry Fork domain. The dominant flow regime of the Great Miami Aquifer impacting the water table beneath OU4 is from the Shandon Trough. Therefore, the 95th percentile of the data distribution for the groundwater background concentrations presented in Table J.2-5 are from the Shandon Tributary.

Background concentrations in the glacial overburden unit are from wells distant from site activities and known sources of contamination. Lithologic correlation is highly variable because of the heterogeneity and anisotropy of glacial sediment. Much of the glacial overburden at the FEMP site consists of clayey till and discontinuous sand lenses. Unsaturated zones within the glacial overburden transition to perched lenses when sandy units are encountered, because of porosity changes and semiconfined hydrostatic pressures. It is possible that past well installations were not consistently screened in saturated sandy zones. Some water may have been collected from a mixture of sands and fracture-saturated clays.

During the course of the Characterization Investigation Study (CIS), surface soil samples were collected from locations within the OU4 boundary in the proposed area for the Silo 3 remediation facility. Samples were collected from a depth of 0 to 12 inches. All samples were analyzed on-site, using high resolution gamma spectroscopy, for Cs-137, Ra-226, Ru-106, Th-232, and U-238. The results for these samples is presented in Table J.2-6. In addition, two samples were sent to an off-site laboratory for additional radionuclide analyses. Radionuclides analyzed for included those measured in the on-site laboratory, as well as, a full range of radionuclides not detected using gamma-ray spectral techniques. Analytical results from the off-site laboratory are presented in Table J.2-7.

Radionuclide concentrations for U-238 ranged from 2.6 pCi/g to a high of 37.4 pCi/g. The mean concentration of U-238 detected in the soil samples collected in the area surrounding Silo 3 was 10.2 pCi/g. Concentrations of Ra-226 ranged from 0.9 pCi/g to a high of 35.8 pCi/g. The mean concentration of Ra-226 detected in the soil samples collected in the area surrounding Silo 3 was 6.78 pCi/g. One sample, FMP-SS-46-206, submitted to the off-site laboratory, yielded a Th-230 value of 295 pCi/g. The ratio of Th-230 to U-238 in this sample is consistent with the ratios of these isotopes in Silo 3, which indicates a potential spill of Silo 3-like material at the location identified by the state-planar coordinates E 1378423.13 and N 480733.44 (approximately 20 feet west of Silo 3). On a site-wide basis, the CIS data confirmed that contaminant concentrations decrease significantly with depth.

Non-validated radiological data from the Waste Pit Run-off Control Removal Action samples collected in the area of Silo 3 and the proposed area for the Silo 3 remediation facility

are presented in Table J.2-8. Both Th-230 and Th-232 were detected in both samples collected for the Removal Action project.

The Waste Pit Area Run-off Control Removal Action included surface soil samples for inorganic analyses in the area surrounding Silo 3 and the proposed Silo 3 remediation facility. Sample results are presented in Table J.2-9. Of the constituents detected antimony, beryllium, chromium, copper, magnesium, nickel, silver, and sodium were consistently above background. None of the surface soil samples were subjected to TCLP analysis.

In addition, samples were also collected for pesticide, semivolatile, and volatile organic analyses. Pesticides were not detected in the collected samples. The only detected volatile compounds consisted of common laboratory contaminants, such as acetone, 2-butanone, and methylene chloride. None of the concentrations exceeded 1 ppm. With the exception of sample number 061126 collected at a depth of 1.5 to 2.0 ft, which contained elevated concentrations of a number of semivolatile organic compounds (SVOCs), SVOCs were at or only slightly above the contract required quantitation limit in all samples. The following SVOCs with their corresponding estimated concentrations were detected in sample number 061126: acenaphthylene (1.3 ppm), anthracene (0.78 ppm), benzo(a)anthracene (4.7 ppm), benzo(a)pyrene (5.2 ppm), benzo(b)fluoranthene (9.7 ppm), benzo (g,h,i) perylene (5.3 ppm), chrysene (3.5 ppm), dibenzo(a,h)anthracene (0.9 ppm), fluoranthene (6.7 ppm), indeno (1,2,3-cd) pyrene (4.2 ppm), phenanthrene (2.6 ppm), and pyrene (8.2 ppm).

Table J.2-5 Background Concentrations for Soil and Groundwater¹

	Background Concentration ²			
	Soils		Groundwater ³	
Analyte	Surface (0-6 inches)	Subsurface (48-54 inches)	Perched	Shandon Tributary
Radionuclides	(pCi/g)	(pCi/g)	(pCi/L)	(pCi/L)

	Background Concentration ²			
	Soils		Groundwater ³	
Analyte	Surface (0-6 inches)	Subsurface (48-54 inches)	Perched	Shandon Tributary
Actinium-227	0.15 ⁴	0.13 ⁴	0.0 ⁵	0.00
Bismuth-210	1.33 ⁶	0.70 ⁶	0.00	0.00
Bismuth-214	1.33 ⁶	0.70 ⁶	0.00	0.00
Cesium-137 ⁷	0.71	0.00	0.00	0.00
Lead-210	1.33	0.70	0.00	0.00
Neptunium-237	0.00	0.00	<1 ⁸	<1
Plutonium-238	0.00	0.00	<1	<1
Plutonium-239	0.00	0.00	<1	<1
Plutonium-240	0.00	0.00	<1	<1
Polonium-210	1.33	0.70	0.00	0.00
Protactinium-231	0.15	0.13	0.00	0.00
Radium-224	0.90	0.96	0.00	0.00
Radium-226	1.45	1.27	1 ⁹	1.77
Radium-228	1.19	1.25	4.57	4.8
Ruthenium-106 ⁷	0.00	0.00	0.00	0.00
Strontium-90 ⁷	0.00	0.00	0.00	0.00
Technetium-99 ⁷	0.00	0.00	0.00	0.00
Thorium-228	1.43	1.25	1.6 ⁹	1.6 ⁹
Thorium-230	1.97	1.85	2 ⁹	2.5 ⁹
Thorium-232	1.36	1.24	<1	<1

Table J.2-5 Background Concentrations for Soil and Groundwater¹ (Cont.)

	Background Concentration²			
	Soils		Groundwater³	
Analyte	Surface (0-6 inches)	Subsurface (48-54 inches)	Perched	Shandon Tributary
Uranium-234	1.24	0.94	1.88	2.43
Uranium-235/236	0.15	0.13	<1	<1
Uranium-238	1.22	0.92	1.5	4.4
Total Uranium ¹⁰	3.71 mg/kg	3.68 mg/kg	1.23 µg/L	2.92 µg/L
Metals	(mg/kg)	(mg/kg)	(mg/L)	(mg/L)
Aluminum	11880	14700	0.123	0.188
Antimony	7.7 ⁸	6.7 ⁸	0.00	0.038 ⁹
Arsenic	8.45	8.79	0.058	0.088
Barium	91.3	99.2	0.477	0.077
Beryllium	0.60	0.62	0.002	0.002
Boron	21.8 ¹¹	42.7	0.00	0.00
Cadmium	0.82	0.59 ⁹	0.006	0.006
Calcium	4340	145000	124000	142000
Chromium	15.5	19.0	0.034	0.067
Cobalt	15.2	15.7	<0.01	<0.01
Copper	14.1	16.3	0.029	0.022
Cyanide	0.25	0.11 ⁸	0.00	0.00
Iron	22300	28000	9.22	4.67
Lead	25.6	13.4	0.021	0.028
Magnesium	3350	43100	48.5	40.7
Manganese	1770	922	0.150	0.514
Mercury	0.30 ⁹	0.29 ⁹	0.004 ⁹	0.0004

Table J.2-5 Background Concentrations for Soil and Groundwater¹ (Cont.)

	Background Concentration²			
	Soils		Groundwater³	
Analyte	Surface (0-6 inches)	Subsurface (48-54 inches)	Perched	Shandon Tributary
Molybdenum	2.6 ⁸	2.7 ⁹	0.028 ⁹	0.02
Nickel	20.9	28.5	0.026	0.026
Potassium	1230	2100	27	4.31
Selenium	0.70 ⁹	0.60 ⁸	<0.003	0.006 ⁹
Silicon	1760	1700	0.00	0.00
Silver	2.6 ⁸	2.2 ⁸	0.038	0.014
Sodium	51.1	198	57.6	52.9
Thallium	0.58 ⁹	0.43 ⁸	0.00	<0.012
Vanadium	30.4	36.9	0.002	0.026
Zinc	62.2	59.0	0.032	0.480
All Organic Compounds	0.00	0.00	0.00	0.00
General Water Chemistry			(mg/L)	(mg/L)
Ammonia	NA ¹²	NA	4.58	18.2
Chloride	NA	NA	97.0	83.5
Fluoride	NA	NA	1.3	1.24
Nitrate	NA	NA	0.286	1.25
Total Phosphorus	NA	NA	0.208	0.979
Sulfate	NA	NA	138	346

¹Data taken from Table 4-1 of the Remedial Investigation Report for OU4.²Source: DOE, 1993a, "Characterization of Background Water Quality for Streams and Groundwater," Draft May 1993, Fernald, Ohio (groundwater); DOE, 1993b, "CERCLA/RCRA Background Soil Study," FEMP, Fernald Field Office,

Fernald, Ohio. Background concentrations are based on the 95th percentile of the data distribution from site-specific background data except as noted.

³All groundwater samples collected for radiological and metal analyses were filtered.

⁴Because of poor Sample Quantitation Limit (SQL) values, this nuclide was assumed to be in secular equilibrium with its parent U-235.

⁵Value assumed to be zero.

⁶Value assumed based on secular equilibrium for radioactive decay chain.

⁷This radionuclide is a fission product, and its presence in the environment is due only to atmospheric releases of radiation (e.g., weapons testing). This radionuclide is not naturally occurring and is only expected to be present at or near detectable activities in the surface soil.

⁸All of the values in the data set were not detectable. The average SQL was substituted as the best representative value for the 95th percentile.

⁹Less than or equal to 10 percent of measured concentrations were above the SQL. The maximum detected value was substituted as the 95th percentile.

¹⁰Individual activity concentrations of the three isotopes for uranium and thorium were converted to mass concentrations. The three isotope mass concentrations were added to obtain the total thorium or uranium mass concentration.

¹¹The calculated standard deviation was greater than 2.00. This was caused by the combination of only 12 values out of 30 above SQL and the maximum concentration of 1140 µg/g. Summary statistics for 0 to 6 inches without suspected outlier were used as the representative statistics for this data set.

¹²NA - Not applicable.

J.2.6 Record of Decision

The OU4 ROD was signed by U.S. EPA on December 7, 1994. The OU4 ROD provides summary information on the Silo 3 history and contents, physical, chemical, and radiological characteristics of the material, a summary of the risks associated with the Silo 3 material, a description of the alternatives analyzed in the OU4 Feasibility Study (FS) and comparative analysis of those alternatives, and a description of the selected alternative. The selected remedy, presented in the OU4 ROD, for the Silo 3 material consisted of the following key components:

- ! Removal of the material from Silo 3;
- ! On-site treatment of the Silo 3 material by vitrification; and
- ! Shipment off-site for final disposition at the Nevada Test Site.

The Administrative Record (AR) for OU4 and the post-Administrative record (post-AR) files for OU4 are available for public inspection at the Public Environmental Information Center (PEIC) located at the Delta Building, at 10967 Hamilton-Cleves Road, Ross, Ohio.

The AR files contain information which supports the OU4 ROD (e.g., OU4 RI, OU4 FS) and the post-AR files contain a record of activities completed after the ROD (e.g., Independent Review Team Report, Value Engineering Report, Explanation of Significant Differences for Operable Unit 4 Silo 3 Remedial Action).

Table J.2-6 CIS Surface Soil Data¹

Sample Number	Cs-137 (pCi/g)	Ra-226 (pCi/g)	Ru-106 (pCi/g)	Th-232 (pCi/g)	U-238 (pCi/g)	Begin Depth (feet)	End Depth (feet)
FMP-SL-46-571	<0.5	11.6	<8.2	<2.2	<23	0.50	1.00
FMP-SL-46-572	<0.6	2.3	<2.4	<2.3	<11.2	0.50	1.00
FMP-SS-46-202	<0.2	0.9	<0.4	0.7	2.6	0.00	0.16
FMP-SS-46-203	0.8	1.1	<3.8	<0.5	12.3	0.00	0.16
FMP-SS-46-204	<0.4	4.5	<3.5	<0.3	5.6	0.00	0.16
FMP-SS-46-206	0.9	4.4	<0.6	<1	<19.4	0.00	0.16
FMP-SS-46-206D	0.9	4.0	<4.2	<2.6	<18.4	0.00	0.16
FMP-SS-46-207	<0.9	5.3	<6	<0.8	6.2	0.00	0.16
FMP-SS-46-208QC	<0.5	8.4	<6	<1.4	7.7	0.00	0.16
FMP-SS-46-318	1.2	10.3	<11	<0.9	<14.9	0.00	0.16
FMP-SS-46-319	<1.4	7.9	<0.5	<2.5	<12.1	0.00	0.16
FMP-SS-46-320	<0.8	1.3	<5.8	<4.3	3.2	0.00	0.16
FMP-SS-46-320D	<0.4	1.6	<0.9	0.6	6.4	0.00	0.16
FMP-SS-46-321	0.5	4.7	<0.6	<4.2	<14.9	0.00	0.16
FMP-SS-46-322	<1	2.0	<3.4	<4.4	6.1	0.00	0.16
FMP-SS-46-323	1.0	4.4	<0.6	<4.6	8.5	0.00	0.16
FMP-SS-46-324	<2.4	35.8	<9	<4	<7.2	0.00	0.16
FMP-SS-46-325	0.4	1.7	<3.2	<2.7	5.5	0.00	0.16
FMP-SL-46-326	<0.9	3.2	<4.9	<4.3	<13.7	0.16	0.50
FMP-SL-46-327	<0.1	1.0	<4.5	0.4	3.0	0.16	0.50
FMP-SS-46-567	<1.9	22.5	<13	<3.2	37.4	0.00	0.16
FMP-SS-46-569	1.1	3.6	<1.4	<0.7	18.9	0.00	0.16

¹ Data taken from Table 4-25 of the Remedial Investigation Report for Operable Unit 4.

Table J.2-7 CIS Surface Soil Data from Off-site Laboratory

Radionuclide	FMP-SS-46-206 (pCi/g)	FMP-SS-46-318 (pCi/g)
Cs-137	2.60	<0.40
Np-237	<0.30	<0.08
Pu-238	<0.10	<0.20
Pu-239/240	<0.10	<0.10
Ra-226	7.00	17.02
Ru-106	<2.00	<2.00
Sr-90	<0.30	<0.90
Tc-99	<4.00	<0.90
Th-228	0.80	1.10
Th-230	295.00	14.00
Th-232	1.00	1.70
U-234	6.10	11.00
U-235	0.40	0.60
U-238	9.30	23.00

**Table J.2-8 Summary of Surface Soil Radiological Analyses
Waste Pit Area Run-off Control Project¹**

	Sample Number RC-0814	Sample Number EM-1815
Sample Depth (feet)	0.5	0.5
Total U (µg/g)	<11	Not Requested
Total Th (µg/g)	<18	<18
Th-228 (pCi/g)	1.4	2.3
Th-230 (pCi/g)	1.8	2.1
Th-232 (pCi/g)	4.4	6.3

¹ Data taken from Table 4-27 of the Remedial Investigation Report for Operable Unit 4.

Table J.2-9 Surface Soil Inorganic Constituents Waste Pit Runoff Control Project¹

Boring Number Sample Number Depth (feet)	WPA18 061121 0.5	WPA35 061240 0.5	WPA37 061254 0.5
Metals	Analytical Results (mg/kg)		
Aluminum	6910	8110	8770
Antimony	28.3	30.2 J ²	20.6 J
Arsenic	3.6	5.1	9 J
Barium	52.6	63.4	75.2 J
Beryllium	0.86 B ³	0.74 B	0.7 B
Cadmium	5.6	5.3	3.7
Calcium	108000	66800	33100
Chromium	13	17	16.7
Cobalt	8.7 B	10.1 B	10 B
Copper	16.2	17.5	18.2
Cyanide	0.12 B	0.11 U ⁴	0.11 U

Table J.2-9 Surface Soil Inorganic Constituents Waste Pit Runoff Control Project¹ (Cont.)

Boring Number Sample Number Depth (feet)	WPA18 061121 0.5	WPA35 061240 0.5	WPA37 061254 0.5
Metals	Analytical Results (mg/kg)		
Iron	13300	15200	19200
Lead	16.5 J	9.9	17
Magnesium	26800	20500	10800
Manganese	471 J	530	522 J
Mercury	0.1 U	0.11 R ⁵	0.11 U
Molybdenum	4.1	4	3.2
Nickel	22.8	27.5	23.2
Potassium	767 B	752 B	1090 B
Selenium	0.43 U	0.44 U	0.54 B
Silver	8	9.1	7.1
Sodium	145 B	97.2 B	86.2 U
Thallium	0.43 U	0.44 U	0.46 U
Vanadium	18.2	22.9	23.7
Zinc	32.9	43.9	49.3 J

¹ Data taken from Table 4-28 of the Remedial Investigation Report for Operable Unit 4.

² J - Estimated value

³ B - Reported value was obtained from a reading that was less than the contract required detection limit but greater than or equal to the instrument detection limit.

⁴ U - Not detected

⁵ R - Results unusable

J.2.6.1 Post-ROD Activities

The post-ROD treatability studies have demonstrated that the implementability of the vitrification technology has proven to be more difficult than originally anticipated. While the development and application of the vitrification technology to the Silo 3 material on a pilot-scale basis has demonstrated that the vitrification of it is technically feasible; it also has demonstrated that continuous processing of the Silo 3 material by vitrification is hindered by the high concentrations of sulfates contained in the waste stream. The high concentrations of sulfates present in the Silo 3 material promote the formation of a sulfate layer on the top of the melt pool and also cause foaming as they breakdown. Both of these events are undesirable.

The combined corrosive nature of the material with the higher operating temperature necessary to destroy sulfates potentially reduces the operational life of the melter components (i.e., refractory), the processing feed rate of the melter and the performance of the support systems.

Techniques to control the affects from the sulfates have been developed; however, this achievement is outweighed by higher operating temperatures, degradation of the refractory, the reduced feed rates of material, additional feed additives, and additional waste generated requiring disposal which lead to longer schedules and increased costs. All these observations have been made under controlled treatability study testing conditions. These affects would be exacerbated under remediation conditions where the Silo 3 material constituents concentrations will vary.

The sulfate concentrations present in the Silos 1, 2, and 3 blend formulations are on average three times greater than the Silos 1 and 2 (only) formulations. Given the aforementioned difficulties experienced in processing sulfates, the higher sulfate concentrations present in the Silos 1, 2, and 3 blend formulations makes the ability to control vitrification production process inherently more difficult than a Silos 1 and 2 (only) formulation.

As a result of the technical difficulties posed by the Silo 3 material to the vitrification process, and their resulting impacts on lengthened schedules and increased costs, the selected remedy is being revised from vitrification to stabilization/solidification. The FEMP has demonstrated, as part of the mixed waste stabilization program, that the implementation of the stabilization/solidification technology would be an effective treatment for the Silo 3 material, through the successful treatment of similar thorium-bearing wastes. This same stabilization/solidification success is shared by other DOE facilities. One of the main reasons for the success of the stabilization/solidification process is the ability to treat material, which is homogeneous in nature, through a technically less complex process. The technical simplicity of the stabilization/solidification process would allow for treatment of the Silo 3 material by a more predictable process and therefore, with a more predictable schedule and cost.

The reexamination of the selected remedy decision for the Silo 3 material has shown that both vitrified wastes and stabilized wastes evaluated in the OU4 FS met all ARARs and were protective of human health and the environment. Both treated wastes would meet the waste acceptance criteria for the disposal facility. Based upon post-ROD treatability study data, these two conclusions continue to hold true for the stabilization/solidification and vitrification alternatives.

Secondary waste streams are also a consideration. The Silo 3 stabilization/solidification process would primarily produce only spent HEPA filters and PPE as secondary waste streams. Wastewater would be recycled back into the stabilization/solidification process. In addition to spent HEPA filters and PPE, due to the high temperatures and acidity of the off-gas, the vitrification process has an inherently more complex off-gas treatment system. The generation, treatment and management of the quench tower, scrubber, and desiccant system wastewater would be avoided if Silo 3 material was stabilized/solidified.

The modification of the selected remedy for Silo 3 material from vitrification to chemical stabilization/solidification or polymer-based encapsulation would not result in a fundamental change to the project. The general remedial actions identified in the OU4 ROD for treatment and off-site disposal of the Silo 3 material would be achieved by the recommended modification of the selected remedy. The modification of the selected remedy for the Silo 3 material from vitrification to either chemical stabilization/solidification or polymer-based encapsulation would require that the OU4 ROD be revised through the U.S. EPA-approval of an ESD document. The ESD documents the technical, regulatory, and programmatic basis for the change.

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